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Economic Performance of Forest Plantations in Vietnam: *Eucalyptus*, *Acacia mangium*, and *Manglietia conifera*

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Abstract: Forest plantations have expanded rapidly in response to financial support from the state and local governments and have had significant positive impacts on rural livelihoods and development in Vietnam, since the late 1980s. This study used net present value (NPV) and internal rate of return (IRR) to examine the economic performance of plantations for three species, *Acacia mangium* Willd, *Eucalyptus* (*Eucalyptus urophylla* S.T. Blake × *Eucalyptus camaldulensis* Dehn), and *Manglietia conifera* Dandy, in Bac Kan province. On the basis of an annual discount rate of 6%, the results showed that rural households earned positive financial returns from forest plantations with seven-year rotations. *Eucalyptus* generated the highest NPV but *A. mangium* generated the greatest IRR. The plantations were facilitated by financial support from the state, land tenure reforms, and wood exports. The results provide valuable business information and policy implications for both local farmers and policy makers. Since the farmers consider more of the short term and economic return of the plantations, the results provide valuable information for policy makers to apply subsidies and other support to promote plantations with significant ecological and environmental benefits for sustainable development of rural economies.

Keywords: forest plantation; cost and benefit analysis; farm household; Vietnam

1. Introduction

The global forest area has decreased from 4.28 billion ha in 1990 to 3.99 billion ha in 2015, but the demand for timber and forest products is expected to have more than triple by 2050 due to the growing world population and changing patterns of consumption [1–3]. To meet the gap, forest plantation areas have increased from 167.5 million ha in 1990 to 277.9 million ha in 2015. Currently, forest plantations are mainly distributed in temperate zones in East Asia, followed by Europe, North America, and Southern and Southeast Asia. The forest plantations are also playing an important role in combating deforestation, climate change, energy crises, supporting livelihood needs, and improving the quality of countries' infrastructures and rural economies [3–9].

Globally, Vietnam leads the world with respect to increasing forest plantations which is in line with a major global shift in domestic wood supplies over the last 50 years [10]. The expanding forest plantations have been used to supply wood, whereas wood supply from natural forests has been shrinking [11,12]. These plantations are mainly non-native species such as *Acacia mangium* Willd, *Eucalyptus*, and *Manglietia conifera* Dandy with an average rotation of about six to seven years. This serves to supply wood for both domestic and export markets [12,13]. Vietnam has become the largest exporter of wood products in Southeast Asia, with the value of forest products reaching USD $8.03 billion in 2017, an increase of almost 10% from USD $7.66 billion in 2016 [14]. In 2012, Vietnam replaced Australia as the country with the most wood chip exports. China, Japan, and South Korea are the three largest importers of wood chips from Vietnam, accounting for more than 90% of Vietnam's total annual volume of timber exports [13,15]. China ranks first, accounting for 60% of the volume of Vietnam's total timber export [15]. Powered by an increased global demand, the wood processing and export industry in Vietnam has been steadily expanding in recent years, promoting rapid growth of land devoted to forest plantations using species such as *Acacia* in Vietnam.

Bac Kan is a mountainous province in northeastern Vietnam, where the tropical climate is characterized by tropical monsoons, divided into distinct rainy and dry seasons, and the annual average temperature is 23 °C, which is favorable for forest plantation. Both natural and plantation forests in Bac Kan are used for timber production and special purposes, such as biodiversity conservation. The total land area of Bac Kan province is approximately 0.5 million ha, and the forest coverage is approximately 70.8% (the largest in northeastern Vietnam). From 2011 to 2016, the forested area increased by approximately 21.6%. Of this, a total planted area of 91,128 ha, in 2018 [16], accounted for 18.75% of the area of the province and 26.25% of the total forest land [17]. The state promotes forestation through several programs and projects, including the Program 327 (Greening the Hills) established in 1992, the Decision 661 (The Five Million Hectare Reforestation) in 1998, and the Program 147 (Production Forest Development Policies for 2007–2015) in 2007, as well as Project KFW (Planting and Rehabilitating Degraded Forests) and Decision 66 (The Production Forest Development Policies for 2007–2015). These programs and projects have contributed to the development of the forestry sector, which has created jobs and improved indigenous livelihoods throughout rural Bac Kan [17].

Many studies have evaluated the economic performance of forest plantations of fast-growing tree species for commercial afforestation and state projects, including the three species analyzed in this study, *A. mangium* [18], *Eucalyptus* [6,19,20], and *M. conifera* [21]. Earlier studies often used cost-benefit methods to calculate the economic performance of several forest plantations species in the long term and proposed methods for improving the economic performance of a forest plantation through enhanced farming techniques that could increase productivity and reduce production costs. However, the economic performance of a forest plantation is actually location and species specific. It is not possible to use the economic performance in one location to interpret the performance in other regions directly. This study fills the gap regarding economic performance of forest plantation and tree species selection in Vietnam.

This study was designed to compare the economic performances of *A. mangium*, *Eucalyptus*, and *M. conifera* in a single rotation. We used net present value (NPV) of one rotation and the internal rate of return (IRR), but various sensitivity analyses were conducted. The results provide adequate information for farm households to use during decision making for the selection of tree species. The study could also help the state and local governments to evaluate and formulate policies that would encourage more ecological forest plantations.

2. Materials and Methods

2.1. Study Area

This study was conducted in rural areas of Bac Kan province in Vietnam, which is located about 160 kilometers north of the capital, Hanoi (Figure 1). Bac Kan has the highest forest coverage with mountainous topography and tropical climate in northeast Vietnam. The province, with a land area of 4.9 million km^2, in 2016 had a total population of 308,300 persons with population density of 63 persons/km^2. Bac Kan is divided into seven districts and one city, and then into 110 communes, 6 wards, and 6 townships [22]. Under the commune system, villages are a type of self-organization for rural people that are not officially recognized as an administrative unit.

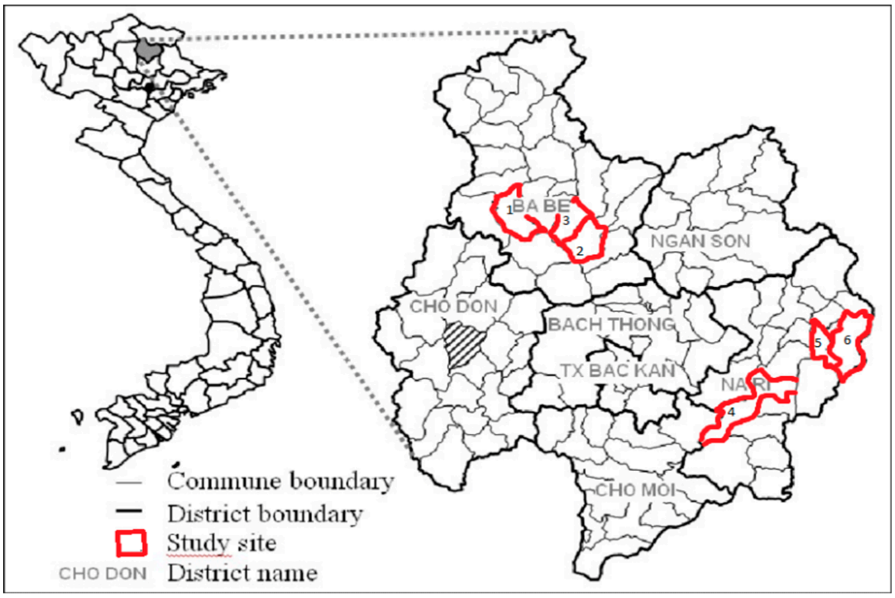

Figure 1. Map of the study area, source [23].

Our study was conducted in the Ba Be and Na Ri districts, which have significant forest coverage of 78% and 66% of the total land area, respectively [17]. The forest resources have contributed to the development of wood processing and handicraft industries, creating jobs and improving residents' livelihoods. The economic structure in Bac Kan remains primarily based on traditional cultivation, with agriculture, forestry, and fisheries as the primary economic sectors. High-yield varieties of crops and livestock have been introduced to replace low-yielding varieties, and new cultivation and breeding have advanced to promote economic vitality. Forest plantations are playing a more important role in contributing to the local economic development.

2.2. Data Collection

Data collection was conducted from June to August 2017. We collected both primary data and secondary data using a survey at the household and village levels. The primary data were collected through face-to-face interviews with household heads or senior household members in their absence. The interviews were conducted by the authors and six local enumerators. Vietnamese or an appropriate ethnic language was used (as required) to conduct the surveys, and the data were recorded in Vietnamese and later translated into English by one of the authors (with crosschecking and random back translations by the author's colleagues to ensure quality).

The questionnaire used in the interviews consisted of the following four sections: (1) The household's socioeconomic characteristics such as demographic attributes, household assets, income sources and level, and the structure of their expenditures; (2) the forest land held by the household, including tenure and land size; (3) the forest plantations operated by the household, including tree species planted and details about the cost of planting and management, and amount of timber harvested, timber prices, and perceptions of management risk; and (4) institutional factors such as financial support the household received from the government. During the interviews, we recorded each household's total annual cash and non-cash income from all major sources to provide a context for income from *A. mangium*, *Eucalyptus*, and *M. conifera* to the household's total income.

We used a three-stage procedure to select a sample of respondents [24,25]. In the first stage, we selected two districts (Ba Be and Na Ri) where a large number of forest plantations had been established between 2010 and 2011. In the second stage, we selected the following three communes from each district that had established numerous forest plantations: Khang Ninh, Yen Duong, and Dia Linh in Ba Be; and Quang Phong, Lam Son, and Kim Lu in Na Ri. In the third stage, we selected one village from each commune based on the village's degree of forest cover and distance to an existing forest plantation and randomly selected 60 households from each village. The resulting sample consisted of 360 households, and we selected the 287 farm households that had reported forest harvest activities in 2017. Then, we had 287 sample households as the primary sample used to conduct the further analysis. Table 1 lists the communes and villages selected and the number of households selected from each village.

Table 1. Village selection and sampling.

District	No.	Communes	Villages	No. of Households Interviewed	No. of Households Selected
Ba Be	1	Khang Ninh	Na Lang	60	45
	2	Yen Duong	Na Vien	60	51
	3	Dia Linh	Coc Pai	60	38
Na Ri	4	Quang Phong	Na Buoc	60	53
	5	Lam Son	Pan Khe	60	49
	6	Kim Lu	Dong Tam	60	51
		Total		360	287

All 287 households had planted *A. mangium*, *Eucalyptus*, and *M. conifera*, and had harvested timber from one to two rotations. In terms of our survey and data for this study, the recent forest plantation was established in 2011. The plantations were established primarily to provide raw wood, peeled boards, and wood chips. Some households obtained free seedlings from the Decision 147 program and technical assistance from district extension officers.

A. mangium is one of the main tree species recognized by the Ministry of Agriculture and Rural Development for development of production forests [26]. Its wood is suitable for the production of paper materials and household furniture [13,27]. *Eucalyptus* plantations were supported by the Vietnamese government's Five Million Hectares Reforestation program (Decision 661), and the Vietnam Ministry of Agriculture and Rural Development designated *Eucalyptus* trees as an important production forest species and a material supplier for paper mills. *Eucalyptus* grows quickly and has the additional benefit of containing large quantities of cellulose [28]. *M. conifera* produces high quality timber that is popular in many industries and is used for construction materials and household commodities, such as, furniture and pencils [29]. These tree species grow well in most of the forest plantations in the study area and suffer from few pests and diseases.

Table 2 presents information on typical growth in height, diameter, and volume of the three tree species at the end of the seventh year since establishment at the study area. We employed a standard plot survey method adopted extensively in Vietnam. First, we selected six households from each commune, from 6 communes. One plot per household x 6 households per commune x 6 communes = 36 total sample plots, and then we had 36 total plots. The plot was 500 square meters, with a length of 25 meter and a width of 20 meter. We counted all trees on the plot and measured 10 trees for their height and diameter. Then, we calculated the average height and diameter of trees of each plot. These results were used to calculate the general characteristics of all samples, including an estimation of the volume of stands on one hectare of forest land.

The cost of forest plantation was incurred mostly in the first three years as follows: The costs for the first year (Year 0) were mainly seedlings and fertilizers and labor for site preparation and planting. In the second year, additional materials for fertilizing and labor costs were required for weed control (twice a year), tending, patch replanting, forest protection, and management. The major investment in the third year consisted of labor costs for tending to the trees, pruning branches, weed control (once), and forest protection and management. Throughout a seven-year rotation, household members managed and protected the plantations. Land rent was the cost of land use. Those respondents who leased lands were required to pay land rent; for other respondents who did not have to pay land rent, the rent was an opportunity cost. At the end of the seven-year rotation, costs were incurred for harvesting the timber and other wood products, for transportation to markets, and for exploitation taxes of the products sold (According to Decree 74, "Detailed Guidance on Implementation of Agricultural Land Use Tax Law").

Table 2. Height, diameter, and volume of forest plantation plots in their seventh year since being established at the study area.

Indicator	Mean	Std. dev.	Minimum	Maximum
1. *A. mangium*				
Height (meters)	16.92	0.70	15.10	17.98
Diameter (cm)	16.36	0.91	14.99	17.88
Volume (m^3/ha)	129.14	8.82	96.43	143.21
2. *Eucalyptus*				
Height (meters)	18.88	1.63	15.98	21.60
Diameter (cm)	17.79	1.43	15.70	20.30
Volume (m^3/ha)	131.73	8.24	109.00	147.90
3. *M. conifera*				
Height (meters)	10.61	1.41	8.80	12.40
Diameter (cm)	14.82	1.13	13.50	17.80
Volume (m^3/ha)	86.62	7.45	75.40	96.60

Source: Field survey data and calculated by author, 2018.

Revenues from forest plantation activities consisted primarily of payments from harvested timber but were supplemented by commercial production of fuel wood. We analyzed timber revenue based on market prices for the three tree species at the end of the seventh year, when the plantation harvest was conducted. Considering inflation, costs and returns were measured for the same year, although they took place in different years. Since the households bear the cost of transporting the products to markets, timber net revenue declines when those markets are relatively far away. On average, *A. mangium* and *Eucalyptus* plantations began to generate fuel wood in the fourth year and *M. conifera* plantations in the fifth year. The volumes of firewood produced varied with the species of tree, but the unit prices for the species were similar, leading to variations in revenue from firewood. The households also obtained a cash subsidy of 3.6 million VND/ha in one rotation from the government.

2.3. Analysis Methods

Our assessment period for the three tree species was the calendar years 2011 through 2017, which coincided with the seven-year rotation commonly used by farmers in the area for those species. This enabled us to use prices reported for 2017 in the interviews of households rather than having to use a fixed price released by a statistical department, resulting in more reliable estimates. Technically, rotations vary for the three species, i.e., about seven years for *A. mangium,* six years for *Eucalyptus*, and nine years for *M. conifera*. However, the respondents indicated that the households typically harvest the trees after seven years following guidance from extension workers and traditional cultivation methods.

We applied net present value (NPV) and internal rate of return (IRR) indicators to evaluate the economic performance of the forest plantations of *A. mangium*, *Eucalyptus*, and *M. conifera* species. Although land expectation value (LEV) is the most commonly used criteria to evaluate economic performance, the NPV we used, here, served a similar purpose. If the cost of land rent is not included, NPV is more similar to LEV for one rotation period. LEV is equal to the NPV plus the present value of the rent. LEV is typically used for perpetual time (multiple rotations), and NPV is used for a certain given time period. Maximizing NPV is equal to maximizing LEV under a given rent and period of time. Since the plantations of the three species in practice had the same rotation, the NPV was a good measure of economic efficiency for this comparison. We used IRR to calculate the rate of return on investment for the plantations as additional criteria. IRR is largely dependent on the intensity of the investment and gives the rate of return. In general, these two methods serve similar functions which is to evaluate the economic performance but they possess some variations if the amount of the investment is different. Hence, we concluded that by using both methods, economic performance of plantings could be assessed more adequately.

The discount rate used in this study was based on the actual interest rates in the districts and relevant studies. In Vietnam, the least expensive loans, which are reserved for households identified as poor or as ethnic minorities, are made by the Bank for Social Policies and are charged an annual interest rate of 5% to 6% [30]. However, the Five Million Hectares Reforestation project under Decision 66 and the Decision 147 programs also provide loans for afforestation efforts via the Bank of Agriculture and Rural Development with annual interest rates of 6% to 7% to households that sign contracts with a State Forest Enterprise (SFEs), state and local organizations that manage forest resources. Thus, we used a discount rate of 6% since most households in the study area had signed contracts with SFEs. This discount rate was close to the maximum recorded IRR for observed stands of trees in previous studies in Vietnam [18,31]. We also used 8% and 10% for comparison before conducting further sensitivity analyses.

We conducted sensitivity analyses to evaluate how our results were affected by different values for the discount rate, timber prices, and land tenure in 2017. The sensitivity analyses assessed how the economic performance of the plantations would be affected by changes in the applied values. This is very important when the data could be less reliable. The most significant impacts on economic efficiency are the discount rate, labor costs, and timber prices and rent, hence how the economic performance would change in response to the changes of these values was investigated.

In the study area, however, most plantations were small in scale and the labor came primarily from family members and opportunity costs are lower than labor costs in the market, leading to greater profits. These plantations also served to create job opportunities though the plantation instead of seeking jobs on the market. In addition, most plantation households in the study area received support from the government for renting land through forest land allocation programs [18].

3. Results

3.1. The Economic Performance: NPV and IRR

The itemized costs and returns are presented in Table 3. The main incomes are from the final harvest in the final year. *Eucalyptus* has the highest value 114.96 million Vietnamese dollars per hectare (VND/ha), followed by *A. mangium* (99.71 million VND/ha), and the lowest is *M. conifera* (83.02 million VND/ha). All have various incomes from firewood sale at years four to six, and the same government subsides of 3.6 million VND/ha in the final year. In this analysis, the major costs occurred during the first year for site preparation, planting and tending, and in the final year for harvesting.

The calculated NPV and IRR, for one rotation, are presented in Table 3. All three species have positive NPV. Eucalyptus plantation generates the highest NPV, followed by *A. mangium* and *M. conifera*. The calculated IRRs are also very high (between 25% and 35%), indicating a much higher rate of return on the investment. It is interesting to note that *A. mangium* plantations generate the highest IRR, but not NPV. This is because NPV is a measure of the value of net return from the investment with a given discount rate, while IRR is a measure of the rate of return from the investment.

Table 3. Cashflow for the forest plantation of three species.

	Manglietia Conifera						*Acacia Mangium*					*Eucalyptus*				
	Year						**Year**					**Year**				
	1	**2**	**3**	**4**	**5–6 ***	**7**	**1**	**2**	**3**	**4–6 ***	**7**	**1**	**2**	**3**	**4–6 ***	**7**
1. Yield (m^3)						86.62					129.14					131.73
2. Cash inflow (10^3 VND)																
2.1 Timber						83,020					99,712					114,957
2.2 Firewood					1600					2000					1800	
2.3 Subsidy						3600					3600					3600
Subtotal					**1600**	**86,620**				**2000**	**103,312**				**1800**	**118,557**
3. Cash outflow (10^3 VND)																
3.1 Basic construction																
Seedling	−2550						−1100					−4500				
Fertilizer (planting)	−2200						−1800					−2200				
Fertilizer (tending)		−800	−800					−800					−800	−800		
3.2 Labor inputs																
Site preparation	−900						−900					−900				
Planting	−1200						−1200					−1200				
Patch Planting								−300					−300			
Tending	−2900	−2000	−1800				−2700	−2000	−2200			−2900	−2000	−1800		
Magt and protection	−250	−250	−250	−250	−250	−250	−200	−200	−200	−200	−200	−200	−200	−200	−200	−200
3.3 Taxes and fees						−3320					−3988					−4598
3.4 Havest & transport						−9000					−12,000					−12,000
3.5 Land rent	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100	−1100
3.6 Other	−800						−800					−800				
Subtotal	**−11,900**	**−4150**	**−3950**	**−1350**	**−1350**	**−13,670**	**−9800**	**−4400**	**−3500**	**−1300**	**−17,288**	**−13,800**	**−4400**	**−3900**	**−1300**	**−17,898**
Net cashflow (10^3 VND)	**−11,900**	**−4150**	**−3950**	**−1350**	**250**	**72,950**	**−9800**	**−4400**	**−3500**	**700**	**86,024**	**−13,800**	**−4400**	**−3900**	**500**	**100,659**
NPV (i = 6%)			**31,348**						**45,243**					**50,728**		
NPV (i = 8%)			**26,124**						**38,882**					**43,319**		
NPV (i = 10%)			**21,553**						**33,304**					**36,824**		
IRR (%)			**26.07**						**34.8**					**32.3**		

Notes: * return and costs per year as they are same for each year.

3.2. Sensitivity Analysis

We analyzed the effect of the discount rate used in the calculations by assuming that it increases from 6% to 34.8%. Figure 2a presents the results of this analysis for the NPV. At a discount rate of 10%, the NPV for *A. mangium*, *Eucalyptus*, and *M. conifera* plantations in one rotation are 33.30 million VND per ha, 36.82 million VND per ha, and 21.55 million VND per ha, respectively. Since the plantations in the study area were profitable, the rates at which NPV is reduced to zero should match the calculated IRRs, 26.07% for *M. conifera*, 32.2% for *Eucalyptus*, and 34.8% for *A. mangium*.

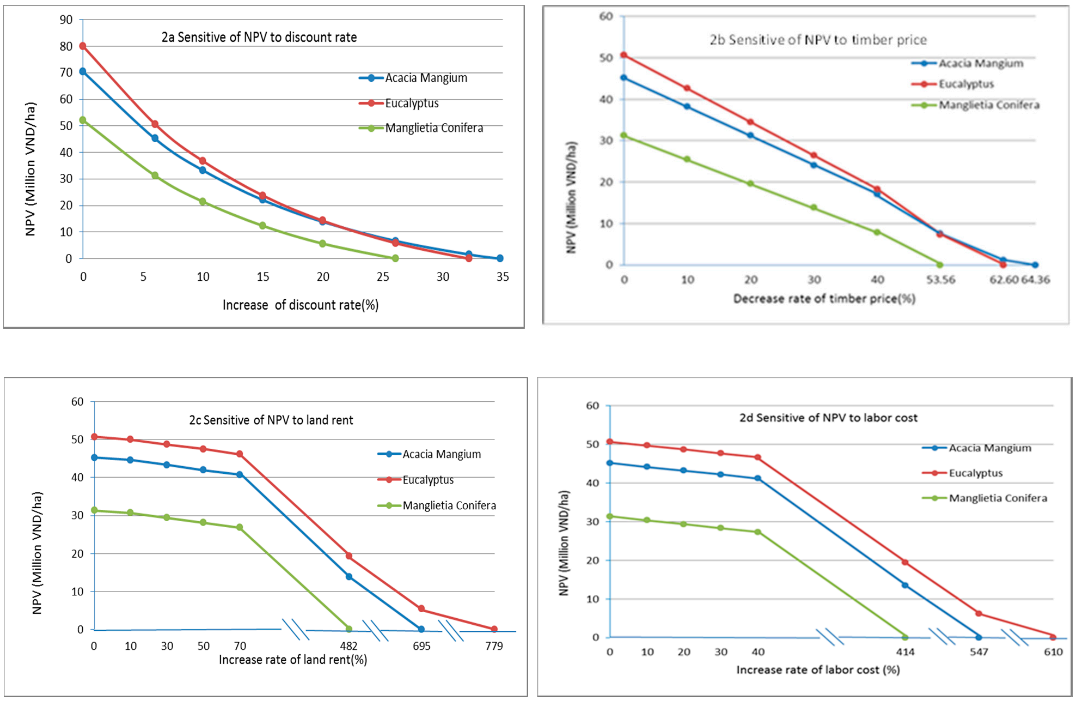

Figure 2. Sensitivity of NPV to the discount rate (**a**); the timber price (**b**); the land rent (**c**); and the labor cost (**d**).

Timber prices directly affect forest planters' revenue, and thus the results of NPV and IRR of the forest plantations. To test the sensitivity of NPV in response to timber prices, we assume that the price is reduced from 10% to 64.36%. As shown in Figure 2b, in this case, the NPVs of *A. mangium*, *Eucalyptus*, and *M. conifera* are reduced to zero when the timber price decreases by 64.36%, 62.60%, and 53.56%, respectively.

In prior analyses of the financial performance of plantations using NPV, land rents typically were added into the cost of afforestation. Noticeably, in Vietnam, Government Decree 02/1994 (Defining the allocation of forestry land to organizations, households, and individuals for stable and long-term use for forestry purposes), which provides support to households planting the three tree species included in this study, led to major changes in forest land ownership and land rental costs in Vietnam. In our study, we assume that the current value of the price of renting forest plantation land has increased at the same rate. The increase of annual land rent is controlled by the Provincial People's Committee, which has set a rate to be not less than 0.5% and not more than 3.0%. In our calculations, we use a land rent rate of 1.1 million VND per ha (Regulation the Land Price List in the Five Years Period (2014–2019) per year and present the results of the sensitivity analysis in Figure 2c. The NPV decreases as the price of land rent increases and reaches zero when the annual rent rate is increased 482% for *M. conifera*, 695% for *A. mangium*, and 779% for *Eucalyptus*. Theoretically, the rent is economic rent when NPV is zero, assuming the cost of rent increased to the point of no profit for the plantation.

Labor cost is one of the factors that greatly affects the NPV. We assume that labor costs increase from 10% to 610% to test the sensitivity of labor costs to the financial performance of plantations (Figure 2d). In this case, the NPV of *M. conifera*, *A. mangium*, and *Eucalyptus* are decreased to zero when labor costs increased by 414%, 547%, and 610%, respectively.

The IRR value indicates the profitability as a percentage of an investment project and helps farmers make decisions about whether or not to continue investing. The IRR is influenced by factors such as fluctuations of timber price in the market, labor costs and land rent costs, etc. Therefore, similar to the case of NPV sensitive analysis, we evaluate how the IRR changes in response to timber price, land, and labor. The results in Figure 3 show that the IRR values of *M. conifera*, *Eucalyptus*, and *A. mangium* approach zero when timber price declines by 62.7%, 69.6%, and 70.6%, respectively (Figure 3a). The IRR approaches zero when the rent increases by 676%, 914%, and 1040% or the labor costs increases by 594%, 758%, and 862% for *M. conifera*, *A. mangium*, and *Eucalyptus*, respectively (Figure 3b,c).

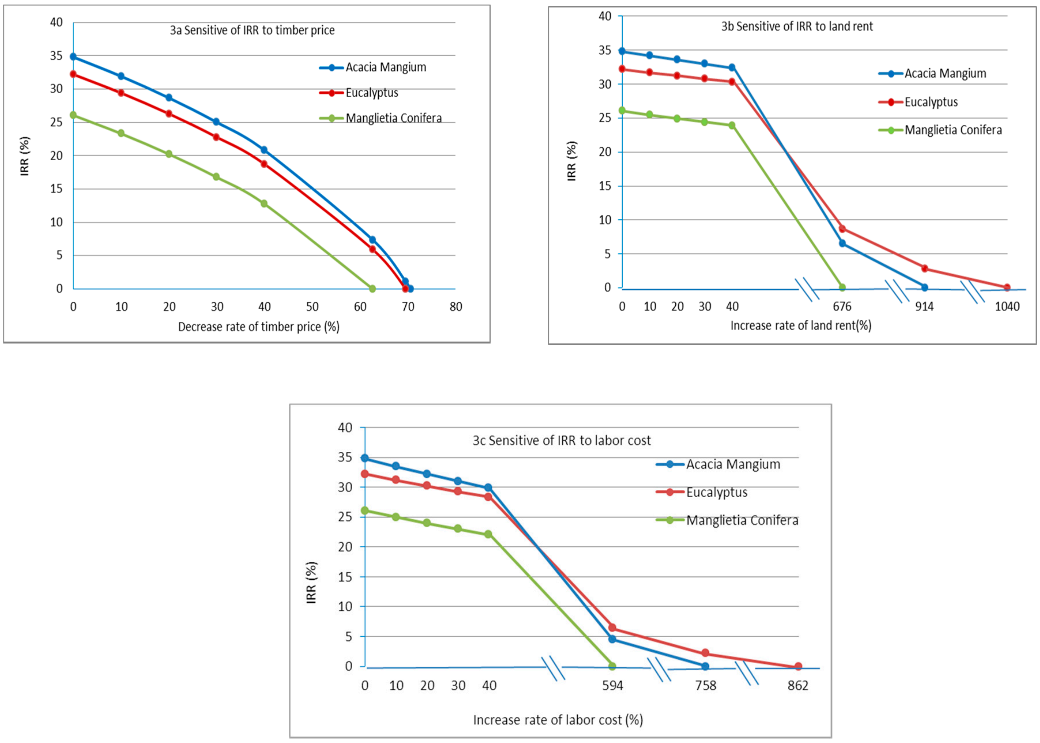

Figure 3. Sensitivity of IRR to timber price (**a**); land rent (**b**); and labor cost (**c**).

4. Discussion

Forest plantations started to expand in Vietnam in the 1990s and have been continuing to grow in the area in recent years. In Bac Kan province, planted forest reportedly increased by approximately 20,000 ha between 2015 and 2018 [16,32]. The expansion of forest plantations occurred in response to government policies aimed at speeding up the process of allocating forest land and granting certificates of land use rights to farmers and at providing support for investments in capital, loans for afforestation activities, cost-sharing of seedlings, and tax reductions [32].

The profits from the planted forests calculated using the NPV would remain high in the absence of the government's financial support [18]. Compared with the total investment for afforestation, the subsidy is very small. For poor households, afforestation is a long-term business activity that only begins to provide revenue after three years and is subject to many risks (fkor example, precipitation, weather, pests, and diseases). They could be incapable of bearing a large one-time investment for establishing forest plantation. Therefore, the limited subsidy should be targeted to the poor households, rather than all households.

Our assessment of the costs associated with establishing and harvesting forest plantations is consistent with costs incurred in the study area. The estimated NPV and IRR appear to overestimate the economic performance as compared with prior studies of forest plantations in Vietnam [18,21]. Specifically, when we compared the financial returns with the planted forest management models in central Vietnam, we found that the *A. mangium* model established by the State forest enterprise had brought higher revenue than the model of the farm households in our study area. Both the NPV and IRR values were smaller than our study, 40.27 million VND/ha, 31% with six year-rotation in the study of Maraseni et al., in 2017 [33] and 27.51 million VND/ha, 28.5% with five year-rotation in the study of Frey et al., in 2018 [34]. However, the NPV and IRR for *Eucalyptus* forest managed by farm households in the study area were the same as the *Eucalyptus* IRR in China (31% for IRR and 3505 USD/ha for NPV) [35] and more than those in Central of Vietnam (23.8% for IRR and 1408 USD/ha for NPV) [34,36].

Possible reasons are rooted in the practice of calculating cost and revenue. Unlike most prior studies [37,38], we applied the wage reported by the farmers hired in forest plantation by other farmers as a labor cost in our calculation, which was most likely an underestimate as compared with actual costs from the labor market. In addition to the potentially biased labor cost, the land rent used in this calculation could also be smaller than the rent in a forest land market. The land rent we used was collected from farmers whose experience in forest land rent resulted from familiar local farmers. Thus, the land rent did not include transaction costs typically needed to facilitate forest land acquisition in the land market. The cost of seedlings in the study area was also low because the government conducted several cost-sharing programs (under Decisions 327, 661, and 147); thus, the households in our sample paid only 50% of the seedlings price in the market.

Discount rate is another important factor affecting NPV. As indicated in Figure 2a, an increasingly large discount rate would reduce NPV. Vietnam is now experiencing a rapid development of the economy. In 2018, the gross domestic product increased by 6.81% in 2017 and suffered from a high inflation rate, for example 3.5% in 2017 [39]. If we has taken into account the impact of inflation, we would have needed to apply a larger discounting rate than we had applied in the calculation, and the NPV would have been significantly smaller. Noticeably, the timber price should be much lower if we use the constant price due to inflation, and then generate a smaller NPV indicating less profitability of forest plantation.

The economic performance should be jointly considered with ecological and environmental impacts of the plantation. For example, *Eucalyptus* is the most productive species in a seven-year rotation and offers the highest NPV, but it exploits the soil nutrients, uses water intensively, and causes soil erosion [6,19]. *M. conifera* has the lowest economic performance, determined by the lowest yield together with the highest price. It is also considered to have less environmental impact than *Eucalyptus*. Therefore, *A. mangium* becomes the preferred species for future plantations because of its high yield and least significant impact on the environment [18]. Some previous studies in Vietnam have found that farm households can intercrop *A. mangium* with commercial crops such as tea and can plant non-timber forest products under the canopies, thereby improving biodiversity and reducing land degradation associated with planting only *A. mangium* [18]. *A. mangium* has rapid growth, high productivity, and economic value, and a large market for its products relative to the other two above tree species [40,41].

Jobs for local farmers were created through *A. mangium* plantation establishment and forest land allocation policies, which reduced the rate of illegal natural forest exploitation and the conversion of natural forests from increased population pressure, as has been pointed out in previous studies [42–45]. Planted forests of *A. mangium* improve degraded ecosystems and offer environmentally added environmental value by rapidly restoring forest cover on savannah hillocks, improving soil quality, and expanding areas of forest directly and indirectly by reducing extraction of timber from natural forests [40]. However, *A. mangium* plantations are vulnerable to various pests, can lead to erosion after clear felling the timber, and prevent spontaneous reforestations [40,41].

Similar to markets for other commodities, the market for *A. mangium* timber from forest plantations presents some risks, including potential reductions in the demand for wood and falling export prices, tree damage from storms and floods before the wood can be harvested, and potential imposition of taxes or other fees and costs in the future as part of the forest and market management policies [41]. Plantations also must be transparent about the origin of their wood products for export to obtain Forest Stewardship Council certification. To minimize these risks, the government has established networks for managers, scientists, timber processing enterprises, and farmers to create sustainable relationships between suppliers and market demanders. In this linkage, the government has an important role to play by serving as a bridge between timber processing enterprises and farmers such as providing legal support in promoting forestry cooperatives to ensure that farmers can be in a better position to sign economic contracts with enterprises. The government also offers training to help farmers to better understand economic contracts to reduce risk in volatility of timber prices.

5. Conclusions

The results of this analysis indicate that *Eucalyptus*, *Acacia mangium*, and *M. conifera* have different NPVs, and offer different IRRs. An overview of the ecological risk and suitability suggests that *Eucalyptus* is the preferred tree species. However, a comprehensive consideration of the ecological and economic factors indicates that *A. mangium* is the preferred species.

A comparison of the significance of timber prices shows that government policies, such as subsidies, play a less important role in profitability of all three tree species. We cannot deduce that government policies are not important for farmers' establishment of forest plantation. Noticeably, forest plantations require substantial initial investments, restricting the ability of farm households to participate due to the costs associated with establishment. To motivate households to participate in afforestation, ongoing revision of current forestry policies in terms of providing access to preferential credit loans is needed to allow farmers to borrow the investment capital needed for production forests and large timber plantations.

The substantial initial investments have more significant restrictions for the poorest households to participate in establishment, even with government support. Due to these restrictive costs, poor household plantations are typically quite small. As a result, forest plantations have only limited positive impacts in terms of improving livelihoods and incomes of poor households [27,46–48]. Therefore, Vietnam's primarily government-based cost-sharing programs should target the poorest households rather than all households.

Furthermore, the government could propose different incentives and subsidies or regulations for different species. On the one hand, plantations must be carefully planned and developed in appropriate areas such as vacant land and bare hills to limit and prevent the destruction of existing natural forests. On the other hand, it should be forbidden to establish plantations in water conservation forests and on steep slopes where soil and water are easily lost. The government could also focus on solving problems associated with planning to plant concentrated forests, such as reasonable forest land plots consolidation and seamlessly creating favorable conditions for reclamation, new plantings and tending, transportation, and harvesting. At the same time, the government could strengthen its inspection and supervision of land uses, landowners' forest management plans, production, and businesses; and resolutely handle and recover allocated areas that have been used ineffectively or illegally.

The government must develop effective quality-monitoring standards for processes such as soil preparation, fertilizer application, and cultivation, thereby reducing the negative environmental impacts of forest plantations as much as possible.

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